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Reduced Image Noise on Shape Recognition Using Singular Value Decomposition for Pick and Place Robotic Systems

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Abstract—***This paper presents reduced image noise on shape recognition by incorporating singular value decomposition. The singular value decomposition is used for image noise reduction for pick and place robotic system. It is possible to find the best approximation of the original data points using fewer dimensions; hereby, processing the edges of the image by smoothening. Experimental studies have been carried out to verify the effectiveness of the proposed scheme. The graphical user interface (GUI) uses the image acquisition toolbox of Matlab and it is used to capture the image. The object borders are decomposed into the vector points in the form of matrix. Results have shown that the proposed method is effective and the robotic arm then enables to determine the object through various tests of the different shapes. By using the proposed scheme, additional functions can be added such as monitoring, roaming, etc. leading to a smart pick and place robotic system.***

Keywords—Noise reduction, Singular value decomposition, Shape recognition, Robotic arm, Vector points

I. Introduction

The pick and place robotic arm is used to reposition an object whether it is in the correct shape or not based on the shape declared to be transported from the graphical user interface (GUI). To initiate the shape recognition, the digital image (top view) of the object is captured. The GUI is programmed to work when a single object is detected by the camera. To ensure the detection of the image and limit the shape to be classified, the object is selected to blend with the environment. The captured image is processed and converted to black and white (B/W) image with its outline detected and changed into a matrix. The matrix shall be decomposed using singular value decomposition (SVD) and it shall be filtered such that only the significant values remains and the rest will turn to zero in order to filter out the noise present and make the outline smoother. The filtered image undergoes in shape recognition. Once the shape matches with the declared shape, the robotic arm shall transport the object into a specific point and when there is a mismatch, the object shall be transported into another location. The system then segregates object, which match and mismatch with the declared shape. The paper is organized as it follows. Section II briefly presents the singular value decomposition, the shape recognition algorithm used in this paper and the methodology. Section III is devoted to the experimental results which are carried out in order to verify the goodness of the proposed method by means of a low voltage robotic arm prototype. Conclusion ends the paper at section IV.

II. Methodology

A robotic arm with four degrees of freedom is then used as the output device performing a pick and place motion when there is a match in the object shape and the selected shape of object is to be transported. The robotic arm serves as the bridge for the software as output device. In the experiment, the robotic arm claw shall close if it recognized the object. The robotic arm during its conception shall rotate to be able to pick an object around it. In this paper, the robotic arm was limited to opening and closing the claw so as to show that it recognizes the object. The image acquisition toolbox is used to capture the shape of an object. The shape specifically the border of the object is decomposed into a matrix of the size equal to the resolution of the camera. The camera is connected to the robotic arm. Singular value decomposition is used to smoothen the captured image for processing in the shape recognition algorithm. Generally, the whole shape is recognized by taking the extrema of the object or the corner of the object. The corner should be clearly defined for proper shape recognition. The user selects the desired shape to be recognized by the software package. Once the shape is recognized, the robotic arm closes the claw. If the object is not recognized, the claw remains open. Fig. 1 illustrates the proposed algorithm for the shape recognition image noise reduction using singular value decomposition for pick and place robotic system. The program begins by showing the GUI. The GUI uses the image acquisition toolbox. The user selects the shape to be recognized. Once the user selects the shape, an object is placed in front of the robotic arm where a camera is placed. The camera captures the general shape of the object. The object border is decomposed into vector points in the form of the matrix. The singular value decomposition is used to smoothen the border of the object for accurate determination of points in the space. The initial state of the claw is open. Once the object matches the shape selected by the user, the robotic arm claw closes. If it does not recognize the object, the robotic claw remains open.

A. Universal Serial Bus Webcam.

The available USB webcams are effective alternatives to serial

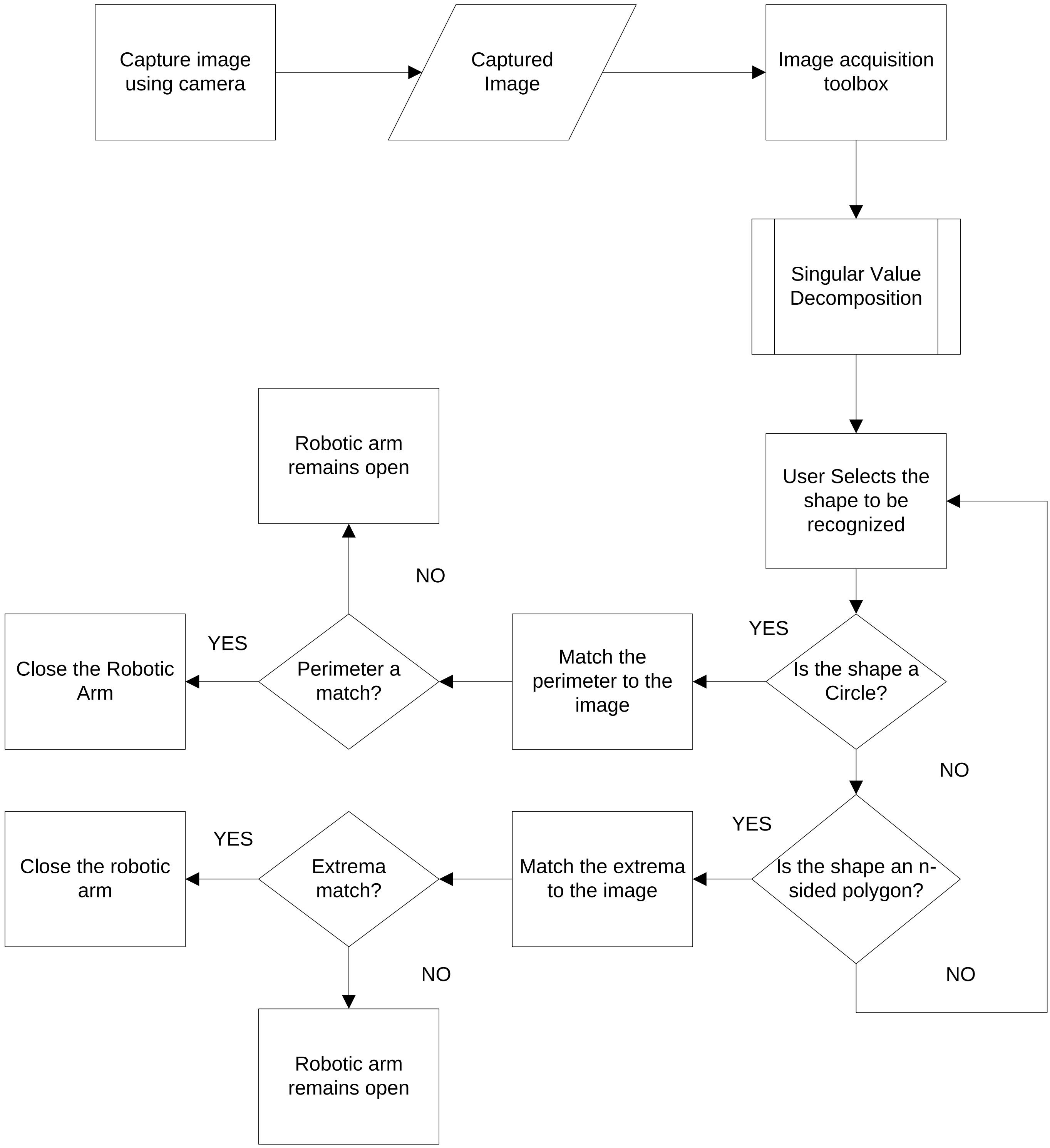

Fig. 1. Proposed algorithm for shape recognition image noise reduction using singular value decomposition for pick and place robotic system.

camera to capture images for shape recognition. The digital image captured by the device serves as the primary input of the system after it has undergone digital image processing via Matlab image processing toolbox. The camera used is the Arkab Web Cam that is developed by CD-R King which provides a resolution of 350K in hardware to 16 MP in software equipped with high resolution VGA CMOS color sensor. It has a frame rate of 30 fps and supported by MS Windows 7 which is the operating system of the computer used where the GUI is loaded.

B. Graphical User Interface Development Environment.

The graphical user interface development environment also known as GUIDE provides a set of tools for creating graphical user interfaces (GUI). These tools greatly simplify the process of designing and building the system GUI. The GUIDE tools can be used to perform the following tasks:

(1.) Lay-out the GUI

Using the GUIDE layout editor, a GUI can be designed easily by clicking and dragging GUI components such as panels, buttons, text fields, sliders, menus, and so on, into the layout area. GUIDE stores the GUI layout in a FIG file.

(2.) *Programming the GUI*

GUIDE automatically generates a program file that controls how the GUI operates. The code in the file initializes the GUI which includes function templates for the most commonly used call backs for each component which is the commands that execute when a user clicks a GUI component. Using the editor, codes can be added to the call backs to perform the functions desired by the developer of the GUI. GUIDE is used to develop the graphical user interface of the robotic arm shape recognition system as shown in the Fig. 2 using the different available components such as push buttons, pop-up menu, axes, and text fields.

C. Shape Recognition Graphical User Interface.

The shape recognition of the graphical user interface (GUI) was developed. After laying out the GUI, the program for the callback function is coded to perform the task that the GUI is supposed to do and that is the shape recognition. Fig. 3 shows the GUI upon execution. The GUI is designed so that the popup menu shall allow the user to select the desired shape to be recognized by the system.

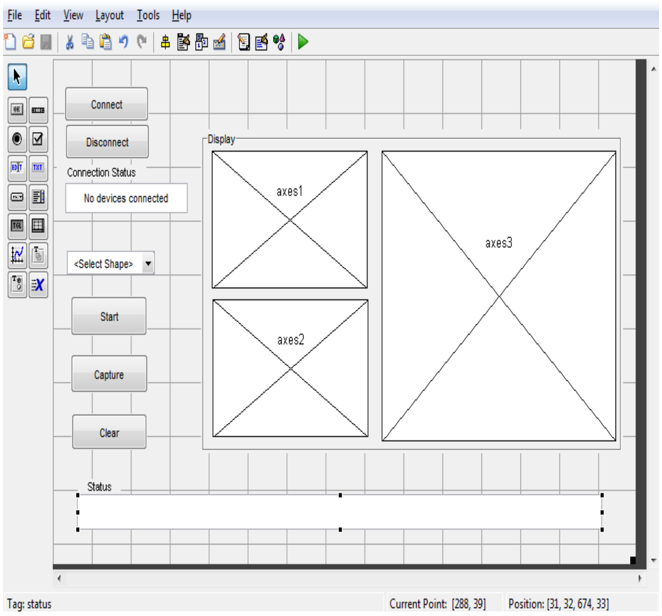

Fig. 2. Graphical user interface development environment (initial HMI).

The 'start' button accesses image acquisition toolbox and opens a window showing a preview of the live feed of the webcam.

III. Experimental Results

A. Image Capture and Pre-processing.

The real time preview of the camera input is displayed. Once the 'capture' button is clicked and there is no shape selected, an error message will be displayed on the text field as shown in Fig. 4. When there is a shape selected prior to clicking the 'capture button' the image acquisition function shall be activated and saves a matrix of the RGB image. Each RGB image is converted to greyscale using the image processing toolbox. A function in the software package is used to automatically compute an appropriate threshold value for use in converting the greyscale image to binary and forming a black and white image. By determining the boundaries present in the image, the number of objects present in the image is then counted. An error message is displayed once a multiple objects are detected to ensure the presence of a single object whose shape shall be recognized as shown in Fig. 5.

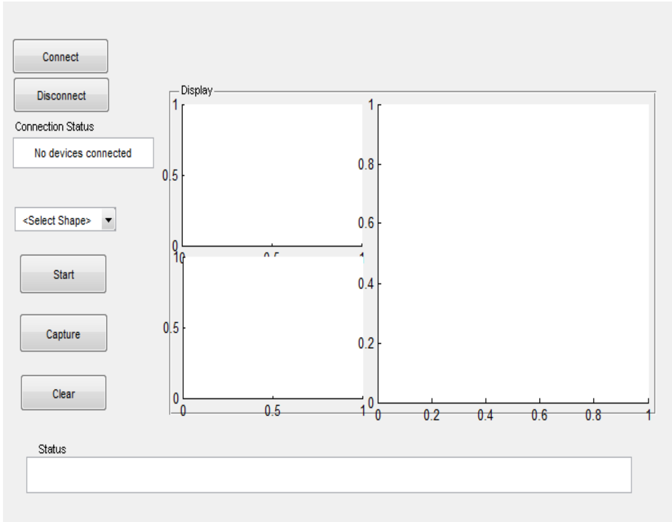

Fig. 3. Graphical user interface development environment (final HMI).

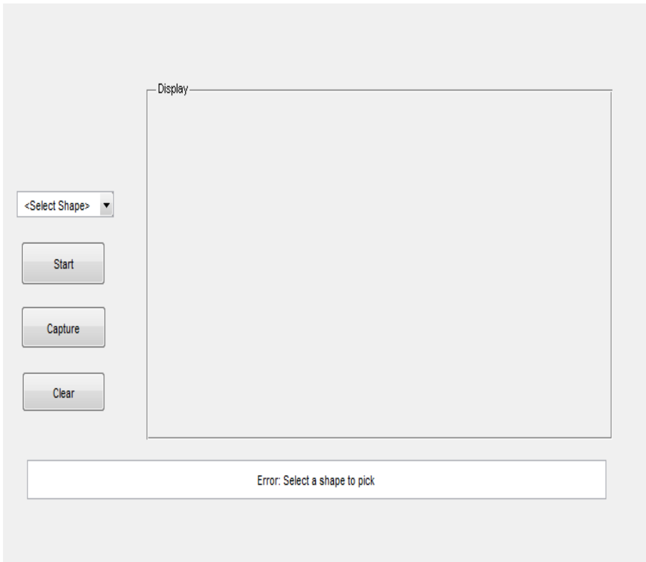

Fig. 4. Error message: select a shape.

The presence of a single object shall display the processing done by the GUI to the image as shown in Fig. 6. The upper left image shows the converted gray scale image of the image captured by the webcam. On the other hand, the lower left image displays the black and white image of the object after the automatically computing the appropriate threshold values. The image on the right displays the image filled with colours and whose outline is then emphasized. The number displayed on the image had a value of 0 or 1. Zero '0' indicates a mismatch of the object shape while one '1' indicates a match. The black and white image matrix is processed to reduce the noise in the image using singular value decomposition.

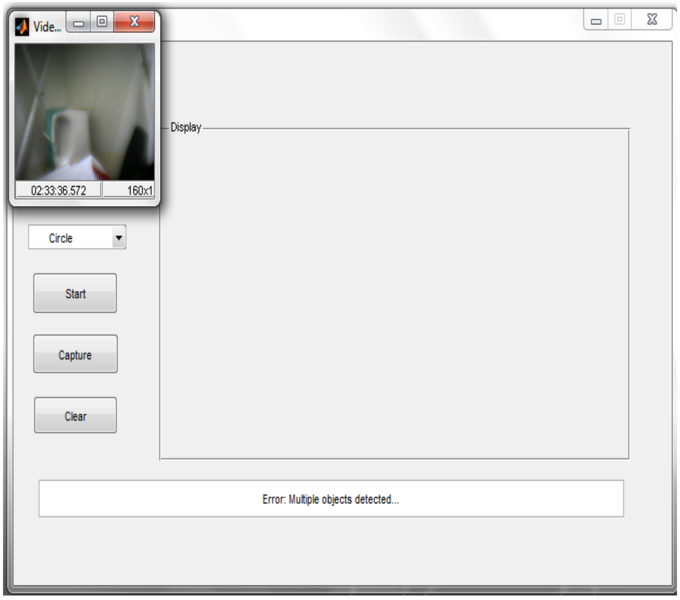

Fig. 5. Error message: multiple objects detected.

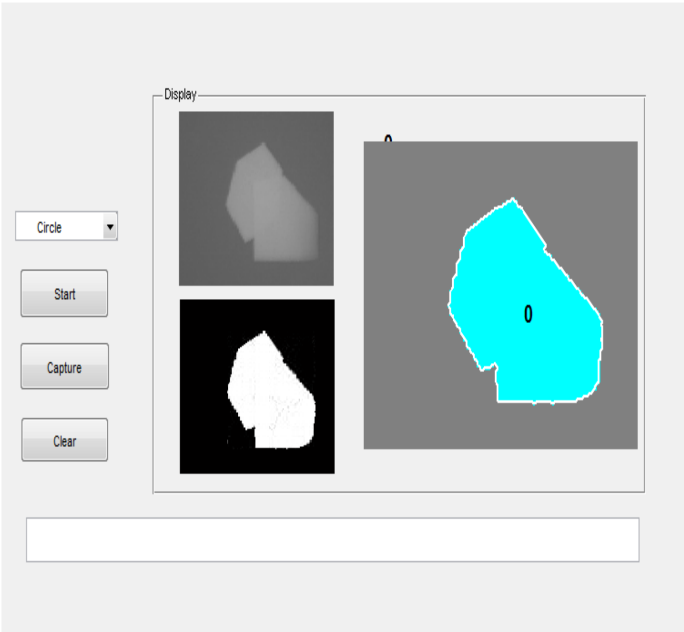

Fig. 6. Processed image by the system (unrecognized shape).

When applied to the GUI, '1' shall be displayed on the image if the shape of the image matches the selected shape as shown in Fig. 7.

B. Shape Recognition Accuracy.

The accuracy of the shape recognition algorithm is evaluated by getting the number of successful trials in a defined number of trials. There are eight view angles per direction evaluated for the accuracy of the system for a total of 64 view points. The system is evaluated first without the use of SVD for noise reduction as the standard.

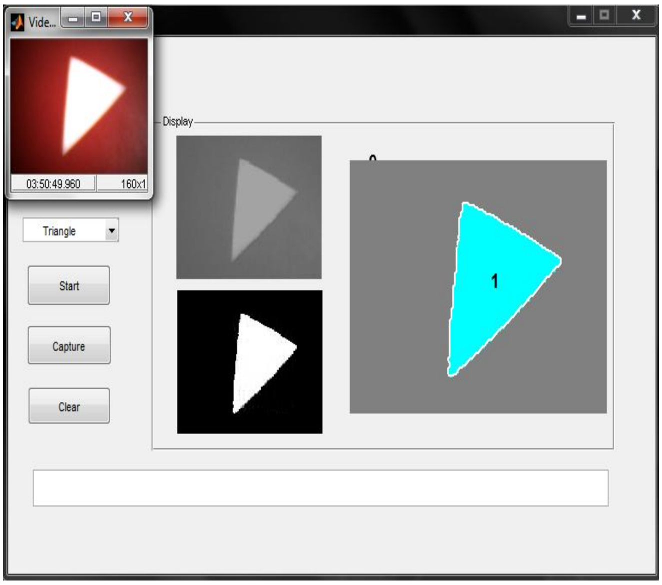

Fig. 7. Recognized triangular shape image.

C. Paired Samples (t-test).

In the paired samples t-test, the null hypothesis in the average of the differences between the paired observations in the two samples is zero. The result of the test has the following form: t=10.027, DF=22 and P<0.0001, since the calculated p-value is less than 0.05 as shown in table 1. Statistically, the mean difference between the paired observations is significantly different from 0, which shows that the application of SVD noise reduction produces a different result.

Table 1. Paired samples t-test for the data accuracy.

	Sample 1	Sample 2
Sample size	9	9
Arithmetic mean	0.6910	0.7882
95% CI for the mean	0.5666 to 0.8153	0.6547 to 0.9217
Variance	0.02617	0.03016
Standard deviation	0.1618	0.1737
Standard error of the mean	0.05392	0.05789

The accuracy improvement shape recognition is shown in Fig. 8. where the accuracy for SVD is closer to the ideal value compared to the shape recognition data without the SVD noise recognition.

Table 2. Accuracy of shape recognition with and without SVD.

Subject	Trial	Accuracy (n=64) Non_SVD	Accuracy (n=64) SVD
circle	1	0.46875	0.5625
	2	0.5	0.609375
	3	0.46875	0.515625
triangle	1	0.828125	0.9375
	2	0.84375	0.953125
	3	0.8125	0.890625
square	1	0.765625	0.90625
	2	0.78125	0.859375
	3	0.75	0.875

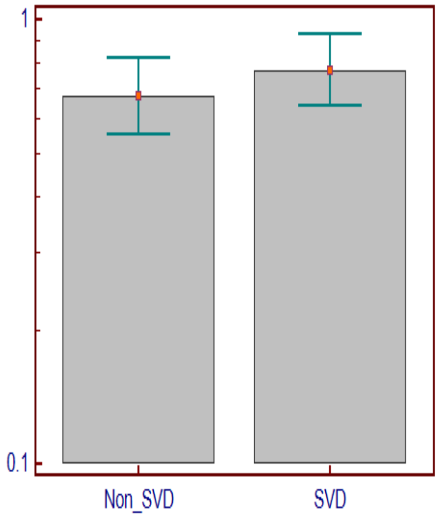

Fig. 8. Data accuracy bar graph.

Table 3. Wilcoxon test for the data accuracy (paired samples).

Sample 1	Non_SVD
Sample 2	SVD

	Sample 1	Sample 2
Sample size	9	9
Lowest value	0.4687	0.5156
Highest value	0.8438	0.9531
Median	0.7656	0.8594
95% CI for the median	0.4731 to 0.8260	0.5690 to 0.9332
Interquartile range	0.4922 to 0.8164	0.5977 to 0.9141

Number of positive differences	9
Number of negative differences	0
Smaller total of ranks	0.00
Two-tailed probability	P = 0.0039

IV. Conclusion

This paper has proposed a reduced image noise reduction using singular value decomposition on shape recognition for pick and place robotic system and their performance is presented. In this method, an improvement is made by applying singular value decomposition to reduce the image noise and the system is able to recognize the shape of objects correctly for circle, triangle, square, and rectangle with over 64 viewpoints. The proposed system has been implemented in Matlab and a hardware prototype is also built to validate the performance of the proposed method. Experimental results show that singular value decomposition is able to reduce the image noise and the pick and place robotic system prototype hence, successfully recognizes the shape of an object. It allows easier detection of the shape as the edges of the image becomes smoother. There is significant improvement in the system when singular value decomposition noise recognition is applied. The system can be readily applied in electronics manufacturing or automation system where visual inspection is utmost important and needed.

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